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LARGE AREA EXPOSURE IN SYNCHROTRON RADIATION LITHOGRAPHY UTILIZING THE STEERING OF THE ELECTRON ORBIT IN THE STORAGE RING

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Synchrotron radition (SR) is a most promising source of soft x-ray (SX) for lithography. However, the vertical divergence (in the direction normal to the plane of the electron orbit) of SX components in SR is too narrow for this purpose.[1] Among the solutions to this problem, the simple sliding of mask and wafer cannot be applied to step-and-repeat mode without involving complicated mechanisms, and the deflection of SR beam with a rocking mirror involves too sophisticated optical designs and deterioration of the mirror due to contamination.

Here we present a third method of expanding the exposed area which utilizes the vertical deflection of SR beam by steering the electron orbit in the storage ring with a time-varing horizontal magnetic field. A similar idea has been suggested by Bets *et al.*[2] but there has been only a brief reference[3] to its experiment.

At the ETL electron storage ring, an additional dipole magnet (S1) is placed as shown in Fig. 1, whose horizontal magnetic field steers the electron orbit vertically. SR beam, which is emitted along the tangent of the orbit, is accordingly deflected and the position of illumination is vertically shifted. Figure 2 shows the change of the vertical

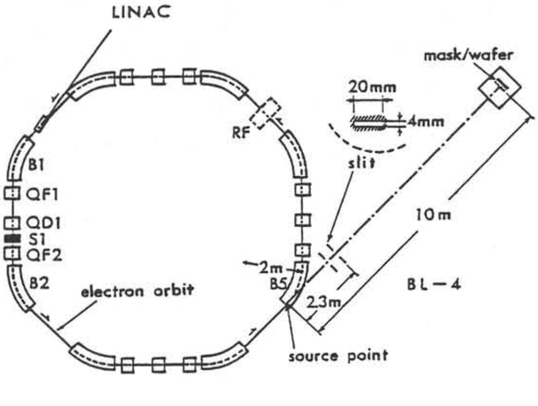

Fig. 1. The storage ring and the lithography beam line at ETL.

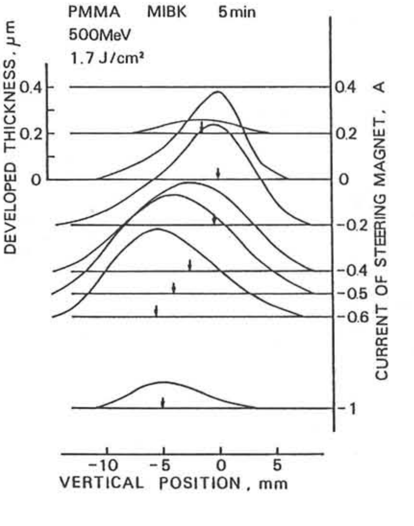

Fig. 2. Shift of the developed thickness distribution.

distribution of the developed thickness in PMMA when the current I_m of the magnet S1 is changed. The magnetic field is about 50Gauss for I_m 1A. The position of illumination is shifted linearly as a function of the magnetic field. In extreme deflections, the illumination is limited by one of the slits settled in the beam line for differential pumping.

When I_m is changed triangularly in time, large area can be scanned by SR beam as shown in Fig. 3. This shows a 2-inch Si wafer, on which the most part is exposed by scanning method while a part in the right side is exposed by ordinary method. Figure 4 shows the vertical distribution of the developed thickness in this wafer. The homogeneously exposed area is extended to about 13mm by scanning method, while by ordinary method the homogeneous width within 10% variation is less than 4mm. If the slit width is enlarged twice as much, it is easy to get the homogeneously exposed area wide enough for the step-and-repeat exposure.

Furthermore, the characteristics of the perturbed electron flux is evaluated by analizing soft x-ray and visible light distribution and their shift with steering magnetic field. The vertical movement of the source point, the tilt of the electron orbit and the vertical standard deviation of electron ditribution are estimated as 4mm/A, 0.9mrad/A and 0.9mm, respectively.

In conclusion, the steering of the electron orbit is proved as a useful technique to expand the SR-exposure area sufficiently for the lithography, without losing the high intensity, horizontal homogeneity and calculable photon energy distribution of SR.

1) H.Tanino *et al.* : Tech. Rept. Professional Group of Solid State Devices, Inst. Electronics and Commun. Eng. Japan, SSD 82-179 (1983) [in Japanese.]

2) H.Betz *et al.* : *Proc. IEEE Int. Conf. Circuits Comput. 1980* (1980) 543.

3) M.Bieber *et al.* : Read at *1983 International Symposium on Electron, Ion and Photon Beams* (June 1983).

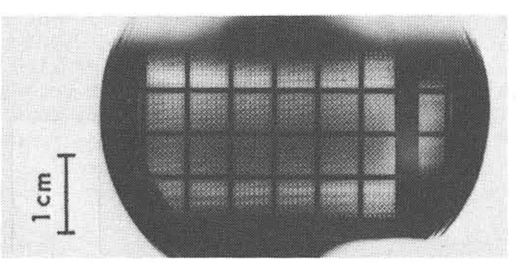

Fig. 3. Exposed area in EBR-9 resist by a scanning method. The ordinarily exposed area is shown in the right part.

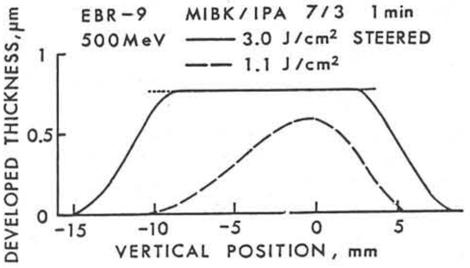

Fig. 4. The developed thickness in EBR-9 shown in Fig. 3 for the scanning (a full line) and the ordinary (a broken line) exposure.